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Morphological and thermal stability characteristics of oil palm frond and trunk by ultrasound-low alkali-based pretreatment

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ABSTRACT

Oil palm fronds and trunks leave a lot of lignocellulosic residues in the agricultural field. Due to its highly complex chemical composition, the lignocellulosic matrix is difficult to break down. This study aims to investigate the effects of chemo-physical pretreatment of oil palm fronds and trunks with ultrasound in a low alkali concentration solution. The microstructure and thermal stability of the oil palm frond and trunk were investigated using scanning electron microscopy (SEM) and a thermogravimetric (TG) method. SEM analysis proved the deterioration of the lignocellulose matrix of the ultrasound-assisted alkali pretreatment compared to raw. According to the TG results, the decomposition temperature curve of treated oil palm shifted to the right side after 50 percent mass degradation, indicating more excellent thermal stability than untreated oil palm biomass. On the other hand, at a temperature above 350 °C, the pretreated biomass has less thermal stability. It has been demonstrated that a combination of low chemical concentration and physical pretreatments can disrupt the oil palm lignocellulose microstructure and potentially shorten the time required to achieve maximum hydrolysis efficiency. Furthermore, ultrasonication power of 300 W, frequency of 40 kHz, temperature of 80 °C, and time of 30 min in combination with low alkali-based pretreatment in oil palm residue will be helpful in applications requiring greater thermal stability.

1. Introduction

Oil palm plantations produce a significant amount of biomass in the form of fronds and trunks. As agricultural by-products, oil palm fronds and trunks are lignocellulosic materials usually abundantly left on the field during pruning and replanting. According to Barcelos et al. [1] oil palm trees can produce 3–8 times more oil per hectare of cropland compared to other oil crops in milder climates or tropical areas. The natural polymer found in plant cells (lignocellulose matrix) provides the rigid construction of plants, which protects against insects and fungi. It is more hydrophilic than polysaccharides, allowing efficient transport of liquids all over the tissues. Also, the highly complex composition structure of lignin makes it difficult to break down (recalcitrance) [2].

The use of ultrasonic waves as a biomass pretreatment technology is becoming more common. This innovative technique has many benefits, including a faster reaction time and improved solute mass transfer in liquid media. Due to mechanical vibration, tiny vapors known as cavitation occur when ultrasonic is applied to a liquid medium. The ultrasound of the lignocellulose pretreatment processes has been reported and shown some alterations that may affect the subsequent process. According to Sharma et al. [3], after the ultrasonication process, the compact structure of biomass transforms into a porous structure, the inaccessible carbohydrate alters into an accessible carbohydrate, and the highly crystalline cellulose converts into amorphous cellulose. It has been suggested that pretreatment of lignocellulose substrate with ultrasonication could be helpful for the intensification of biomass bioconversion [4]. The ultrasonication pretreatment process is required to depolymerize the lignin and cleave lignin-carbohydrate linkages and loosen the structure. Ultrasonication with chemical pretreatment

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